GEMINI

La Palma Herstmonceux

Newsletter of the Royal Greenwich Observatory

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THE WILLIAM HERSCHEL TELESCOPE

Some million years ago, the island of La Palma was created in spectacular violence, rising as a volcano from the floor of the Atlantic Ocean 300 kilometres off the shores of Africa. The volcano, long extinct, left its *caldera*, the crater shell, to form the main structure of the island. The highest point on the rim of this caldera is 2400 metres above the Atlantic, and is known as the Roque de los Muchachos, the Peak of the Boys. Just below the Roque sits the set of telescopes constituting the international Observatorio del Roque de los Muchachos. The site scenery is magnificent: in front of the telescopes, to the north and west, the Atlantic stretches away to its blue horizon. Behind the telescopes, to the south and east, sheer cliffs drop thousands of feet into the gentle green and pine-clad slopes of the caldera interior, the agricultural heart of the island. The site is also superb astronomically.

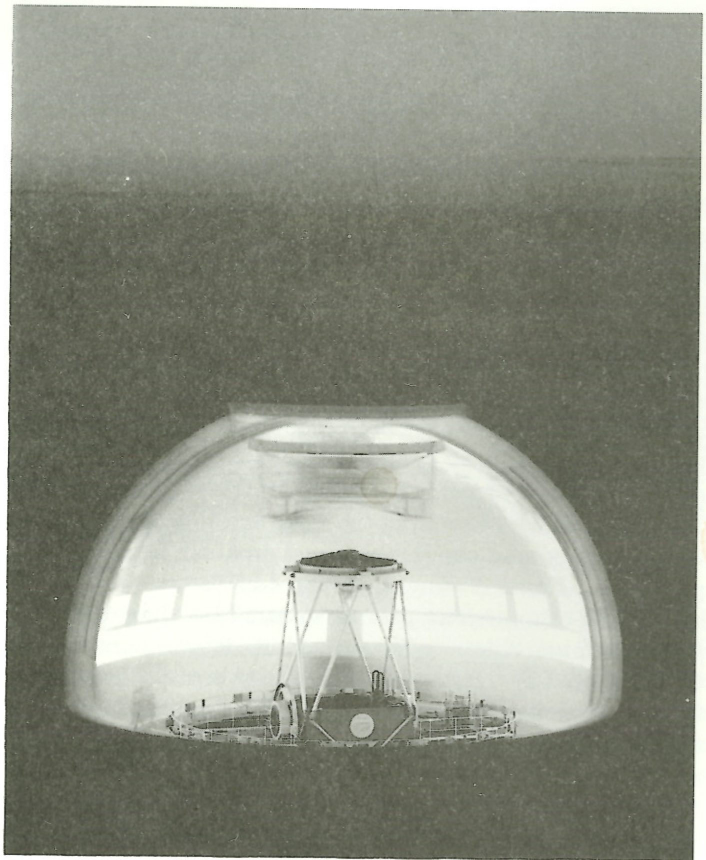
At the Observatorio, the 4.2-metre William Herschel Telescope (WHT), the flagship of British optical astronomy, is undergoing final engineering and instrumentation. The astronomers have arrived to begin observations.

1. The telescope

It is fitting that the major telescope on this stupendous site is of a dramatic and novel design.

The primary mirror is 4.2 metres in diameter. This makes it the third largest single-mirror telescope in the world: but in many senses it will be second to none. It is, for instance, the largest single-mirror *common-user* telescope; the two larger ones, the Hale 5-metre at Mount Palomar and the USSR 6-metre, are not readily available to international competition for time. It is on one of the finest sites known for astronomy: the stable atmosphere and the clear night sky will result in a photon-gathering power and imaging quality which is expected to exceed any of its rivals. And advanced British design means that the effective area of the telescope is greater than that of other "4-metre class" telescopes. For instance, although the ratio of diameters of the William Herschel Telescope and the Anglo-Australian Telescope implies that the former has about a 16 per cent advantage in collecting area, the real advantage, because of relatively smaller central obstruction, is 25 per cent. The total collecting area of the primary is about 12.5 square metres, 134 square feet.

The novel design has been produced by the Royal Greenwich Observatory in conjunction with Freeman Fox and Partners;



A night-time shot of the William Herschel Telescope inside the open dome manufacture was by Grubb Parsons Ltd (Northern Engineering Industries plc) in Newcastle. (It is for Grubb Parsons the last telescope in a long line - the firm is no longer in the business.) The design is the bringing together of many strands. One strand is the "learning curve" for UK optical telescopes (and for the RGO/Freeman Fox collaboration in particular) for which the William Herschel Telescope represents the present peak; along this curve lie the Isaac Newton Telescope (2.5 m; 1967 at Herstmonceux and at La Palma as of 1984), and the Anglo- Australian Telescope (3.9 m; 1974 at Siding Spring Observatory, New South Wales, Australia). The most striking feature of the design is the altitude- azimuth ("alt-az") mounting, which is the original way of mounting large telescopes: such telescopes rotate on a flat circular track to correspond to a bearing around the horizon, and move in altitude to obtain the correct elevation. Herschel's telescopes were of this type (Figure 1). It is paradoxical to note the great advance for astronomy when the equatorial mount was invented; combined with mechanical (clockwork) or electrical motors, such telescopes could track the stars precisely.

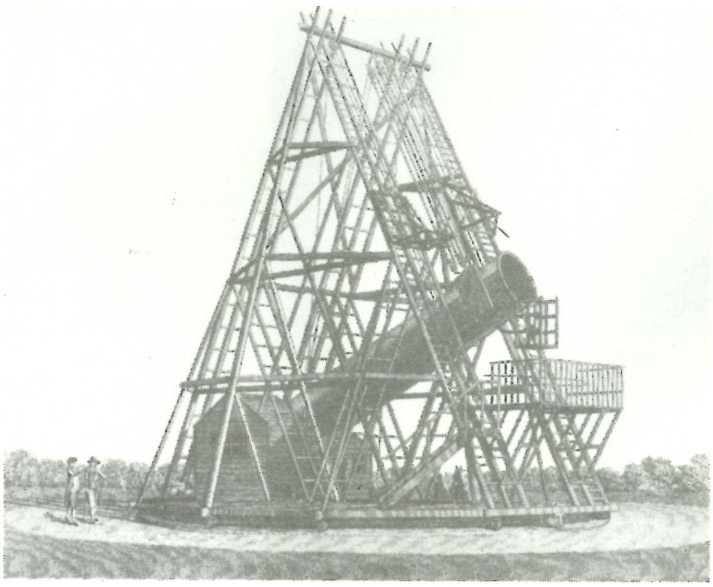


Figure 1. William Herschel's major telescope

Computer technology now makes equatorial mounting unnecessary. The most humble home computer can convert Right Ascension and declination into altitude and azimuth fast enough to provide appropriate drive signals to alt-az electric motors for accurate tracking. There are great cost and operative advantages in mounting the major moving structure of a telescope on a flat rather than a tilted bearing. Radio telescopes have been mounted this way ever since the great MkI dish at Jodrell Bank was built in 1953. Yet one more design strand is necessary for the William Herschel Telescope, which came from the mechanical genius of Victorian inventors, and one inventor and amateur astronomer in particular. James Nasmyth, inventor of the steam-hammer and holder of numerous patents in canal building, built the first "trunnion-vision" telescope on an alt-az mounting (see GEMINI No. 3). Nasmyth's idea was to add a third mirror to a Cassegrain telescope with an alt-az mount, deflecting the light beam out of the telescope tube along the altitude axis through the trunnion supporting the altitude bearing. Nasmyth could sit on a stool mounted on the azimuth bearing with his eye to the trunnion. In his words, he was too old to climb a ladder to the stars, so he brought the stars down to him. He sat in relative comfort with his eye at the trunnion, while his fellow astronomers climbed to the prime focus, or contorted themselves to get at the Cassegrain focus. Nasmyth's telescope was of such fine optical quality that he was the first to observe the solar granulation.

The result of these strands is shown in the cutaway design of Figure 2. The two deflected foci (the Nasmyth foci) are served by two large horizontal platforms which can take heavy, complex instruments, and hold them horizontal in a fixed gravity field. In contrast to the necessarily heavy rigidly-boxed instruments which mount at the moving primary and Cassegrain foci, the Nasmyth instruments can be simple optical benches of laboratory type. Astronomers thus have the opportunity of trying out novel experiments without the need for major design engineering and construction. The Nasmyth scheme offers another advantage: versatility, in that by folding the Nasmyth mirror in or out, the astronomer can select any of three stations rapidly - the Cassegrain focus, or either of the two Nasmyth foci. Thus a choice of instruments is available as conditions change during the night, or as the complexity of a particular experiment demands.

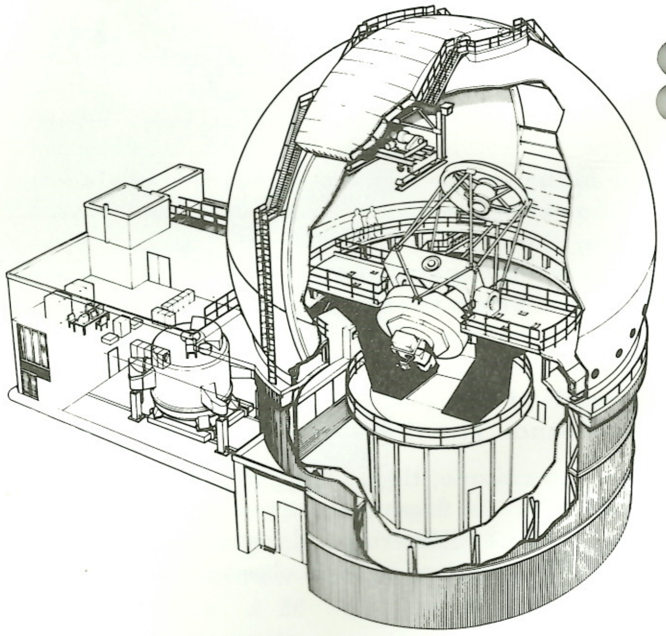


Figure 2. A cutaway drawing to show the design of the William Herschel Telescope

The paraboloid primary mirror of the William Herschel Telescope is made of Cervit, a glass-ceramic material having near-zero coefficient of expansion over the range of operating temperature. The precise diameter of 4.2 m was determined by availability of the mirror blank, made by Owens-Illinois. The acceptance tests of this mirror showed that it is the most accurate large mirror yet made, concentrating 85 per cent of the light from a point source (star) into an area 0.3 arcsec in diameter. A three-element correcting lens before the prime focus provides an unvignetted field of 40 arcmin diameter; the effective focal ratio of the primary with this corrector is f/2.8.

For operation at Cassegrain or Nasmyth foci, a convex hyperboloidal secondary mirror redirects the light from the primary either through the central hole in the primary to the Cassegrain focus, or to a third main mirror, a *Nasmyth* flat angled at 45 degrees which can be motor driven into position at the intersection of the axes to divert the light sideways to either Nasmyth focus. It is interesting to note that the secondary is slightly larger in diameter than the primary of the Jacobus Kapteyn Telescope. The secondary mirror assembly is mounted in a rotating top-end ring which allows changes between prime-focus and Cassegrain/Nasmyth focus to be carried out semi automatically and rapidly (about 30 min).

The primary mirror is mounted on an array of 60 pneumatic (gas) cylinders together with an axial defining system which locates the mirror in its correct axial position with three reference points around the mirror edge. In a transverse direction the mirror is supported in the standard way by weighted levers coupled by link arms to brackets connected to the edge of the mirror. However, one of the many advantages of the alt-az mounting is that the mirror does not rotate with respect to the gravity direction; and the simplified weighted-lever and linkage system is arranged to act only in the vertical direction.

The drive system for the William Herschel Telescope is another triumph for the alt-az design: identical precision straight-spur gears are fitted to the two axes of the telescope, with driving torque supplied by two direct-current torque motors supplied from individual power amplifiers sharing a common control signal. Absolute position is obtained from a pair of gear-driven shaft encoders on each axis. Because of the symmetry with respect to gravity and the very compact (short focal length) design, the telescope is extremely responsive to this drive system. Frequencies of oscillation are high - the structure "rings" at 4 Hz or above - and the implication is that setting is precise, without wobble or backlash. The telescope pointing accuracy is designed to be 1 arcsec. The positive response also allows quick setting: the slewing speed is 1 deg/sec for each axis.

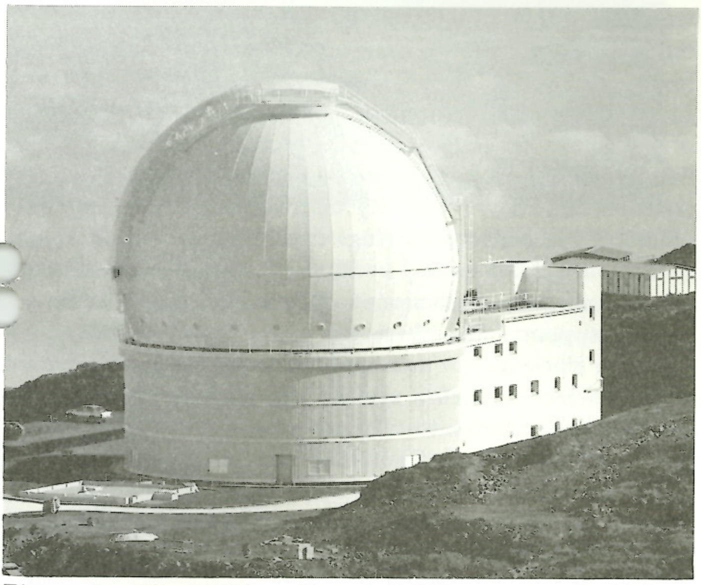


Figure 3. The William Herschel Telescope on La Palma; building and dome

A third triumph of the design is the relatively small dome which the alt-az mount allows. The dome can hug the symmetric telescope much closer than one of (necessarily off-centre) equatorial design. A small dome is not only a cheap dome, it is also one in which the minimal internal volume contributes the minimum to dome "seeing", degradation of the resolution by thermal refraction cells in the dome air. It is also ventilated easily. For La Palma, the dome aperture was purposely made wide, and large extractor fans are incorporated in the cylindrical building design. The dome is designed to be cold - no heating, of course, and with minimum heat leakage from the adjoining building. In addition, it has screens and cavity walls to minimize the effect of the bright clear mountain sunshine striking the dome and its supporting walls. A pair of up-and-over shutters with windscreen coupled to the lower shutter allows observation down to 12 deg above the horizon. Set on one side of the cylindrical drum which supports the dome is a three storey rectangular annex of conventional construction which contains the operations control room, computer room, workshops, some offices and other services. The building and the distinctive onion-shape of the 21 m diameter dome are shown in Figure 3.

The alt-az mounting provides cost and engineering benefits, but one or two astronomical and technical challenges as well. One major consideration is that as the telescope tracks a star field, the focal plane projected on the sky is rotated. For the William Herschel Telescope both the primary and Cassegrain instruments are mounted on turntables which match this rotation during telescope tracking. Another consideration is cabling - what happens to it when the telescope is rotated? The problem is dealt with by what is conventionally known as a cable-twister, in reality a cable untwister. For the William Herschel Telescope, cabling passes from the building pier, through the azimuth cable twister, up one column and over an altitude cable-wrap to the telescope tube centrepiece. The cable twister has feeding through it a dry-nitrogen line, 6 high-pressure oil hoses, and a total of 144 (multi-core) electrical cables, some measure of the complexity of driving and instrumenting a modern optical telescope. For the astronomers, the alt-az system poses some minor programme planning difficulties, ones which radio astronomers, well versed with alt-az telescopes, readily understand. In particular the telescope can rotate ± 270 deg about due East; astronomers will need to exercise care in choice of slew direction to the next object to "unwind" the azimuth rotation so that they do not have to stop the next integration when a 270-deg limit is encountered. Even more fundamental is the zenith "blind- spot", through which objects cannot be tracked continuously, because this would require an instantaneous spin in azimuth through 180 deg. However, slewing speeds and accelerations are such that the blind spot is only 0.4 deg diameter, and the interruption for an object passing exactly through the zenith lasts but 3 minutes.

To visitors entering the ground floor of the distinctive onion-shaped dome, the telescope is a remarkable sight. It towers upward, gleaming in its new white paint, squat, dominated by its large Nasmyth-platform "ears", and seemingly too large for the snugly fitting dome. No large pockets of warm air here to damage the stable, tight images which we know the La Palma site produces!

2. The observations

The capability of any telescope depends not only on size but also directly on its quality of instrumentation. The instrumentation determines the efficiency with which light can be detected, and to a great extent the spatial and wavelength resolution which can be achieved. The instrumentation for the William Herschel Telescope is in a state of continuous development, but a core set of instruments nears completion; and a subset of the instruments is complete. Figure 4 shows the disposition of these core instruments at the four main focal stations of the telescope. The core set is as follows: a versatile intermediate-dispersion double spectrograph (ISIS), a fixed-format highly-efficient low-dispersion spectrograph (the Faint Object Spectrograph, or FOS), an imaging Fabry-Perot interferometer known as TAURUS II, a high-resolution spectrograph (this is known as the Utrect Echelle Spectrograph, UES), infrared instrumentation not yet fully specified, a prime-focus camera for photographic or electronic (CCD) detectors, an Image Photon Counting System (IPCS II), and a Charged-Coupled Device (CCD) camera. Both the latter are area detectors which will have several head units to operate as detector systems for all instruments. The majority of observations in the early years of the telescope will probably be done with ISIS, TAURUS II, and the FOS, and some further comments on these instruments are thus in order.

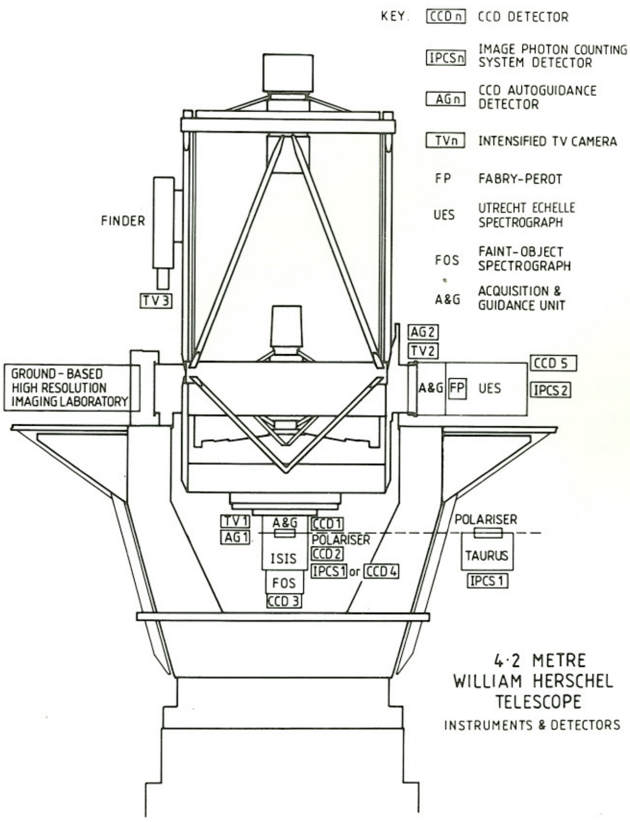


Figure 4. Schematic outline showing the arrangement of the instruments and related equipment at the four principal foci of the William Herschel Telescope

ISIS is a versatile Cassegrain instrument consisting of two spectrographs which can be operated separately or simultaneously; one is optimized for the blue and the other for the red spectral region. This is to be a main workhorse instrument of the telescope, and is being produced in collaboration between the RGO and Oxford University. The main design goals are the following: a range of dispersions between 130 and 16 Åmm^{-1} in the first order; maximum possible throughput, high operating efficiency in setting up the experiment and in observing; rapid interchange between ISIS and FOS, which share the same slit assembly; long-slit, multi-slit, and fibre-feed capabilities; spectrophotometric capability; cross-dispersion capability to give total wavelength coverage simultaneously from 300 to 1100 nm with a resolving power of about 2000. It is anticipated that the demand for this versatile instrument will keep it on the telescope for more than 50 per cent of the time; the astronomy which can be done with it ranges from spectral investigation of bright stars at relatively high dispersion to very faint objects (quasars, distant galaxies) at relatively low dispersion.

FOS on the other hand is not versatile; it is a collimator-less fixed-format spectrograph designed to have the utmost efficiency at low dispersion over a very wide wavelength range. It is dedicated to chasing the spectra of the faintest objects which astronomers can observe. The FOS has been built in a collaboration between Durham University and the RGO; a similar (and very successful) spectrograph was so built for the 2.5 m Isaac Newton Telescope (see GEMINI No 15). It is essentially complete, and awaits commissioning on the telescope.

TAURUS is a wide-field (9 arcmin) imaging Fabry Perot interferometer originally developed by RGO and Imperial College London. It uses a servo-controlled scanning etalon as a narrow-band tunable filter. Effectively TAURUS allows two-dimensional images to be recorded of emission-line objects in many adjacent narrow wavelength bands; typical observing programmes consist of the study of gas in external galaxies, HII regions, supernova remnants and other kinds of nebulae. A new automated version, TAURUS II, has been built by the Kapteyn Sterrenwacht Werkgroep in Roden, the Netherlands, with some technical input from RGO. This instrument is complete, and is now assembled at the William Herschel Telescope.

In normal use, the telescope and the instruments are controlled remotely from an operations area in the console room adjacent to the telescope. Here the data are recorded in a computer system, on disk and tape backup. The large console room also has a major data-reduction computer system, which will be used by astronomers who have completed their observations. Eventually this computer will be used to perform much of the analysis of the data *on-line*; the astronomer will walk away from the William Herschel Telescope with data reduced and processed, leaving him or her free to concentrate on analysis and understanding of the results. A further development is imminent - with the linking of the computer systems at La Palma into wide-band communication systems, true remote observing will be available. Astronomers may eventually be observing from their town offices. Dramatic cost savings from less travel and accommodation will not ensue - because substantial expenditure is required in data-transmission, in monitoring and in on-site level of support. But there will ensue substantial improvements in efficiency for astronomers, less time in travel, more time in science. Such a system also enables rapid changes between programmes to take advantage of changing observing conditions. Some limited remote observations of fixed design are carried out now at other sites. All the infrastructure of the William Herschel Telescope has been designed with this possibility in mind.

This way of the observing future has one sad consequence - some astronomers will miss the beauty of La Palma.

3. The present state

The William Herschel Telescope has seen first light; an image obtained at the (uncorrected) prime focus is shown in Figure 5.

At the time of writing (31 July), short-exposure images have been taken at both primary and Cassegrain foci. Image quality is excellent; on two nights during the commissioning, subarcsecond images have been obtained. The telescope points to an accuracy of 5 arcsec all over the sky, and tracking is excellent. Dome-following is in operation; the dome runs quietly and smoothly, producing no noticeable telescope vibration when either tracking or slewing.

The interim A/G box has been commissioned, as have integrating TV systems for acquisition and autoguiding. The first instrument (TAURUS II + IPCS II) has been assembled at the telescope, and connected through the telescope cabling. Calibration signals, requested by astronomers from the control room, have been recorded by the data-acquisition computer in the control room.

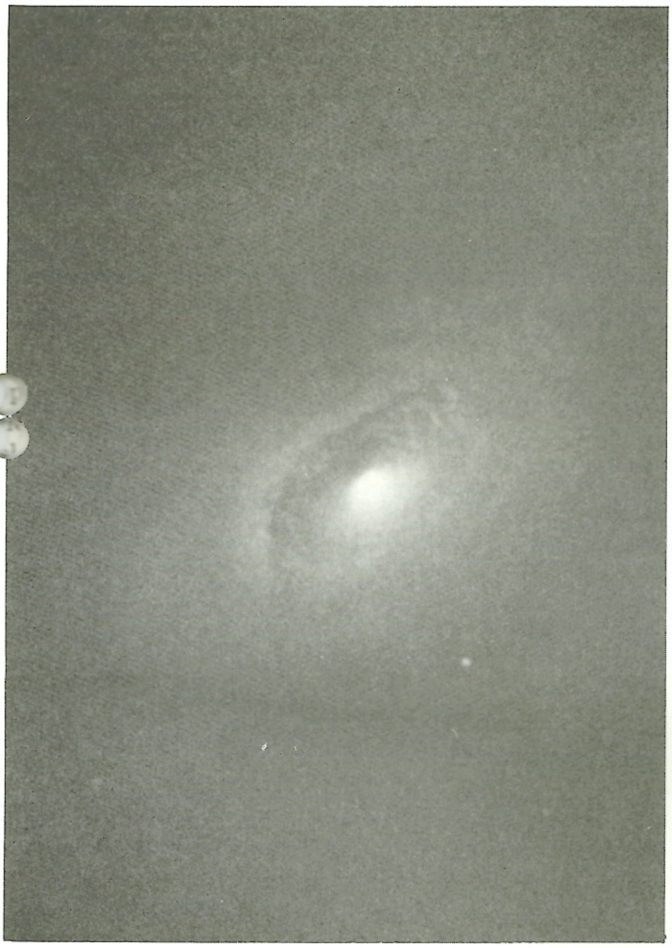


Figure 5. An image from the William Herschel Telescope commissioning programme. The object is M64 (NGC 4826), the 'Black Eye' galaxy. The image is from an integrating TV system mounted at the (uncorrected) primary focus, and the exposure time was 0.04 seconds.

The telescope is basically ready for observers, and the first observations are confidently expected in mid-August.

4. William Herschel

In 1753 William Herschel was 16 and an oboist in his father's regimental band in Hannover, Germany. At the age of 28 he was a well-established musician in England, the appointed organist of the Octagon Chapel in Bath. By 34 he was increasingly devoting time out of his busy sequence of musical engagements to astronomy, and he had begun to build his own telecopes. He died at the age of 83 at Observatory House, in Slough, Fellow and Copley Medallist of the Royal Society, Court Astronomer to George III, and a knight of the realm for his outstanding contributions to science. His remarkable career, from musician to astronomer, from Germany to Britain, is the subject of many detailed studies. He was an amateur astronomer up to the age of 43. As an amateur he discovered the planet Uranus, the first planet to be found in recorded history. This brought Herschel instant fame; but he was already well known in professional circles for building telescopes to a standard which the Astronomer Royal (Maskelyne) conceded were superior to those of the Royal Observatory. Subsequently, his astronomy was always carried out with the finest telescopes in existence. It is also worth noting the breadth of his astronomical research, from solar-system studies (sun, moon, planets, asteroids, comets) to double stars (the first catalogues), to sky surveys, to the nature of nebulae, to the "structure of the heavens". Herschel gave birth to the science of observational cosmology, and was the first to postulate evolution for the universe, via clustering processes to form galaxies, and via condensation of nebulae to form stars.

There are so many ways in which it is appropriate that the flagship of UK optical astronomy should bear William Herschel's name. Observational cosmology is expected to be a main research theme. There is the alt-az mount. It is almost exactly the 200th anniversary of Herschel's major telescope, the "40-foot"reflector (Figure 1). There is the fact that the WHT is a general purpose one which will look at planets, the solar system, and the most distant galaxies known, just as Herschel did. The optical quality surpasses other telescopes - as did Herschel's telescopes. And surely the beauty of the site would not have been lost on someone who appreciated the glory of nature and the beauty of music to the extent Herschel did.

Herschel made fundamental discoveries which changed the face of his science and man's view of the universe. The scientific community has had the vision to provide an instrument on a site which gives the international community of astronomers the chance to do likewise. The challenge is one of near-infinite dimensions; but infinite excitement. We had better rise to it.

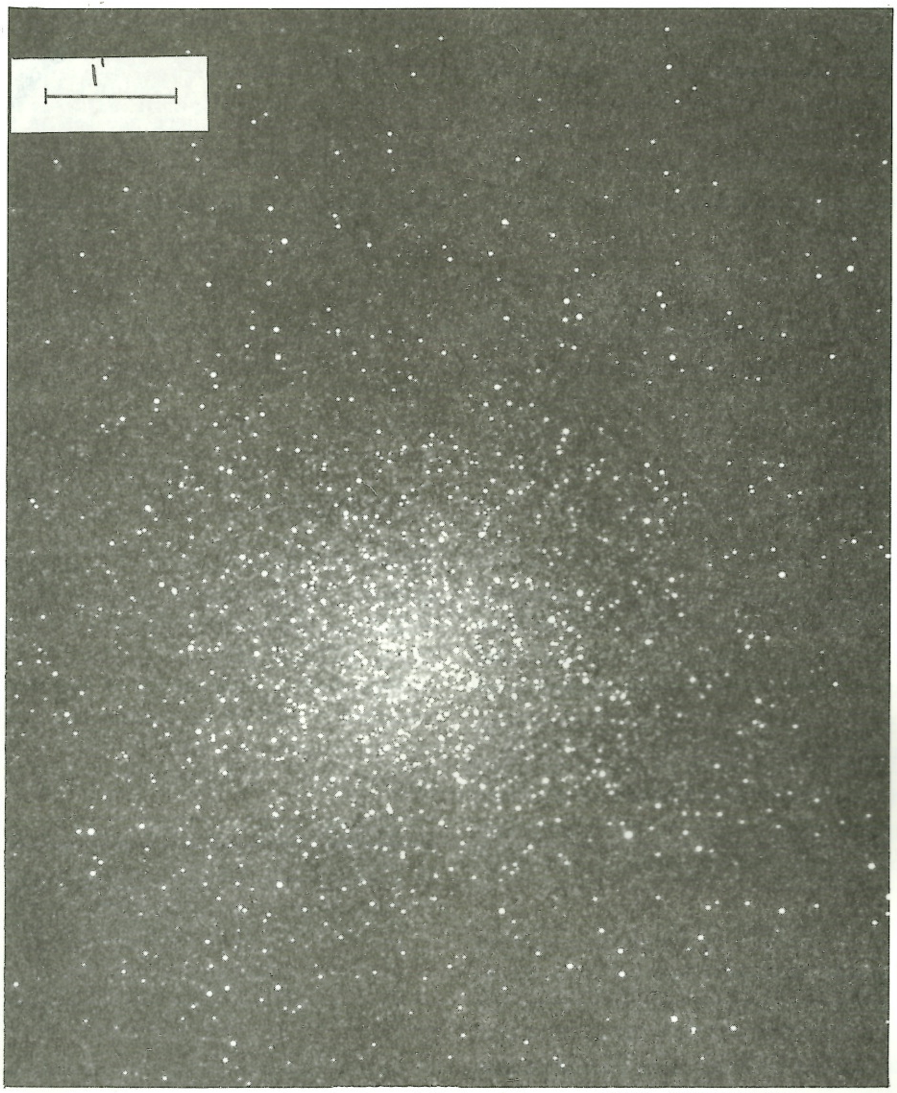
Jasper Wall

Taking Pictures of Accretion Discs

We show how the shapes of the emission lines from the accretion discs in cataclysmic variable stars can be used to image the disc. When applied to dwarf novae, this method has produced unexpected results related to the effect of the gas stream upon the disc.

Whenever gas has to accrete onto a compact object, and it has angular momentum to lose, it may first form a disc of material surrounding that object, known as an accretion disc. Accretion onto a black hole is the most efficient method of energy generation known which has led to the suggestion that quasars are powered by accretion, and the well defined orientations of accretion discs also suggest a role in the formation of the highly collimated jets observed in radio galaxies and in the remarkable star, SS433. Many suggested occurrences of accretion discs have yet to be proved, and so we have to turn to simpler systems for solid data. Of all objects, the close binary systems, and in particular the cataclysmic variable stars and low mass X-ray binaries, offer us the cleanest examples of accretion discs. A combination of a compact primary star and a low mass secondary star gives an ideal combination of radii and luminosities which lets the accretion disc dominate from ultra-violet to infra-red wavelengths.

M13



This photograph of the globular cluster M13 (NGC6205) was taken on 1987 August 8 at the Cassegrain focus of the William Herschel Telescope using the JKT plate camera during the commissioning programme of the telescope. A 20 minute exposure was made on unsensitised IIaO plates without filter. Full moon was August 9!

Peter Gray

EDITORIAL

My work at RGO does not normally take me to La Palma so I was particularly pleased to be able to spend a few nights there recently. Apart from being dutifully impressed by the technical changes since my last visit in 1984, I was particularly struck by the number of new faces - staff who have spent very little or perhaps no time at Herstmonceux before transferring to the island and, of course, there were also Spanish and Dutch staff whom I did not recognise. I spent ages studying the 'Rogues Gallery' in the INT building (why do people not look like their photographs?) and wondered how many people knew *me*. Perhaps visitors should wear name-tags!

I received the criticism that staff on La Palma do not feel that GEMINI is their newsletter: there is too much gossip from Herstmonceux. To these people I am sorry. To remedy this, I hope to revive the *'Letters from La Palma'* feature which we had in earlier issues. Now there is a VAX link between us, text (or better TeX) files can be MAILed to [MJP] on the VAX 750 or 780 at Herstmonceux for inclusion in GEMINI. I hope other La Palma/VAX users will also make use of this facility.

GEMINI was so named to reflect the two parts of the RGO's present existence, which I hope will not be forgotten as staff are recruited from outside.

Margaret Penston

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